The Ohio State University: School of Earth Sciences

Grain Size Analysis of Submarine Landslides in the Nankai Trough

Tyler Rohan, Derek Sawyer

Introduction

Background

Submarine landslides are fine-grained, gravity-driven, landslides that have approximately equal parts water and solid by volume (Sawyer et al. 2012). The impact of submarine landslides ranges from the generation of large tsunamis to the creation of turbidity currents that disturb biological seafloor communities. Submarine landslides are among the largest sedimentary transport processes on Earth and often comprise 50% of the stratigraphic record on continental margins (Moore, 2014). Submarine landslides are geohazards that can affect both society and industry because of their ability to influence tsunamis and damage offshore pipelines or telecommunication infrastructure.

Research Goals

1. Conduct a detailed downhole grain size analysis of a prominent submarine landslide deposit (MTD-B) from International Ocean Discovery Program (IODP), Site C0018.
2. View and map this submarine landslide deposit (MTD-B) as well as the underlying "Pink" Volcanic Ash horizon in three dimensions using reflection seismic data.

Two important factors in defining the post-failure behavior of any mass transport deposit (MTD) such as a submarine landslide are grain size composition and pre-failure water content. This study focuses on a prominent landslide in the Nankai Trough, offshore Japan. Such data will provide valuable insight into the dynamic behavior of landslides along this active margin.

Bathymetry Map and Seismic Profile of Drill Sites

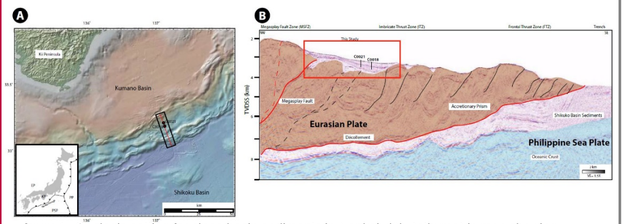


Figure 1: Geologic setting for slope basin sediments in Nankai. (A) Bathymetric map showing location of IODP sites C0021 and C0018. Modified from (Moore and Sawyer, 2015) Black rectangles show location three-dimensional seismic volume and red line indicates the location of the seismic line transect. In set map shows the tectonic setting and plate configuration of Nankai Trough. (B) Seismic profile indicating the major tectonic regions within the accretionary prism. The Slope basin studied here lies seaward of the megasplay fault zone. (Strasser et al. 2011)

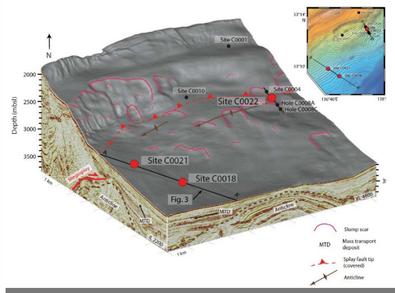


Figure 2: Detailed surface morphology and structure of the slope basin at the footwall of the splay fault. The sites in red shows IODP Expedition 338 sites. Solid black line through Site C0021 and C0018 is location of seismic line A-A' shown in Figure 4. IL: in-line, XL: cross-line. Modified from (Strasser et al. 2011).

Methods

Grain-Size Analysis

Hydrometer analysis of 50 sediment samples from IODP Expedition 338, Site C0018 was completed because of the fine-grained nature of the sediments.

- Samples were collected from 90.17-191.17 meters below the sea floor (mbsf).
- Samples were collected at approximately 1 sample per 1 meter of core.
- Samples were chosen to best represent the particle size distribution in the mass transport deposit (MTD-B) located 128.46-188.65 mbsf.

Seismic

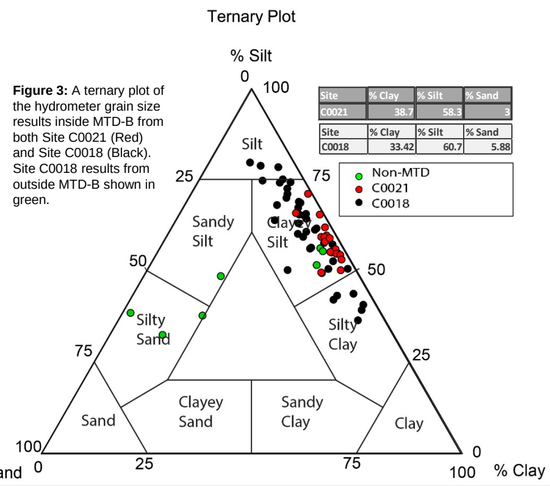
3D seismic data was acquired by Petroleum Geo-Services (PGS).

- The total area surveyed was 791 kilometers in size and acquired on the *M.V. Nordic Explorer* in 2006.
- Data was viewed and mapped using the Kingdom Software ®

Results

Hydrometer Analysis Results

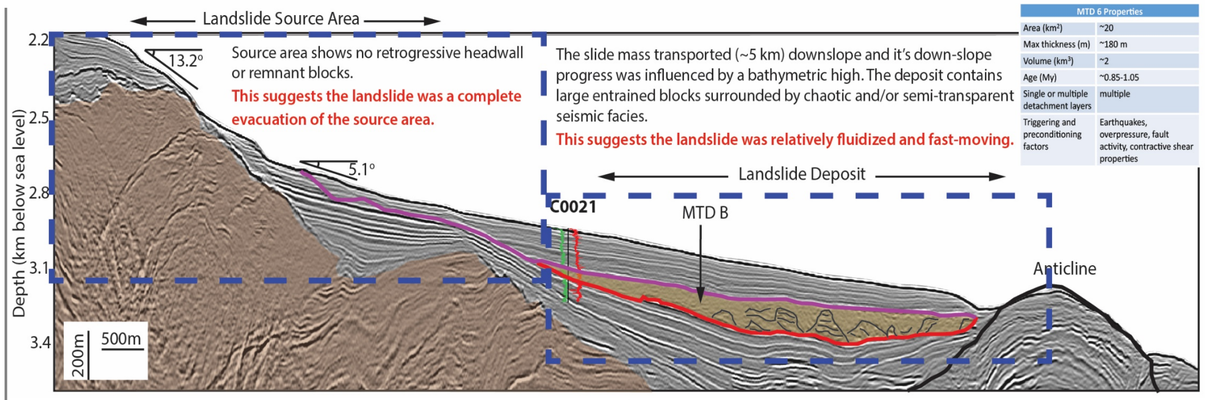
- The composition of the submarine landslide is primarily Clayey Silt (≈78 %) with some Silty Clays (≈15 %) and Silts (≈7 %).
- The grain size data shows a fining upward pattern suggesting that the landslide had a large flow factor during deposition.
- Data from site C0018 has been mostly consistent with that of site C0021 located 2 kilometers away.
- However, there were noticeably more variations in the grain size data from site C0018 than from site C0021.
- There was a significant increase of sand at the detachment surface of the landslide.
- Increased sand is due to a coarse volcanic ash layer that underlies MTD-B and is only found at Site C0018.



Site	% Clay	% Silt	% Sand
C0021	38.7	58.3	3

Site	% Clay	% Silt	% Sand
C0018	33.42	60.7	5.88

Figure 3: A ternary plot of the hydrometer grain size results inside MTD-B from both Site C0021 (Red) and Site C0018 (Black). Site C0018 results from outside MTD-B shown in green.



Seismic of Sites C0021 and C0018

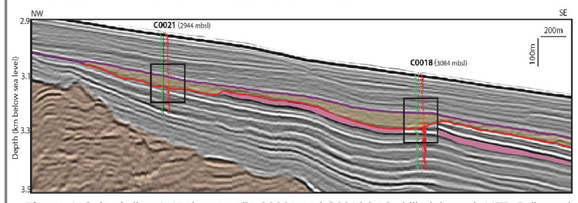


Figure 4: Seismic line A-A' shows wells C0021 and C0018 both drilled through MTD-B (brown). The mapped pink horizon under Site C0018 suspected "Pink" volcanic ash layer.

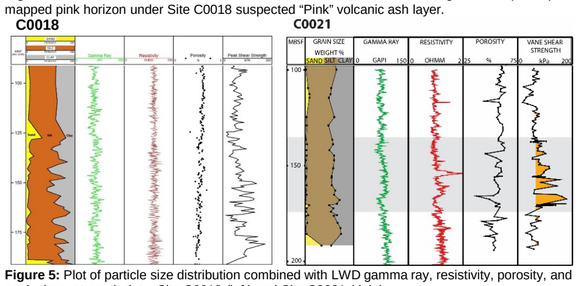


Figure 5: Plot of particle size distribution combined with LWD gamma ray, resistivity, porosity, and peak shear strength data, Site C0018 (left) and Site C0021 (right).

Mapping Results for "Pink" Volcanic Ash

- The ash layer has been found to be regionally widespread and able to be mapped using reflection seismic techniques.
- The volcanic ash layer correlates with the "Pink" Volcanic Ash event (0.99-1.05 Ma) from Kyushu Island, Japan discussed in (Hayashide et al. 1996).
- The seismic data shows other submarine landslide deposits away from MTD-B that are also overlie the volcanic ash layer.
- Through seismic analysis it is shown that the submarine landslide deposits displace parts of the volcanic ash layer.
- This displacement that was most likely caused by fast-moving and fluidized debris flow and is the reason the volcanic ash layer was only discovered from core samples at Site C0018.

3D View of Landslide Deposits over "Pink" Volcanic Ash

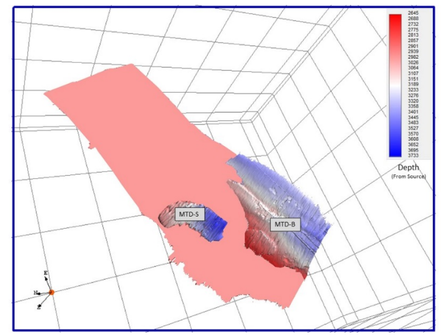


Figure 6: 3D Image showing the volcanic ash layer (pink) overlain by MTD-B from Site C0018 (right) and another large surficial submarine landslide deposit (MTD-S) found during seismic analysis

References

Ando, Masataka. (1975) "Source Mechanisms and Tectonic Significance of Historical Earthquakes along the Nankai Trough, Japan." Tectonophysics 27.2 (1975): 119-40.

Alves, Tiago M., Kuncho Kurtev, Gregory F. Moore, and Michael Strasser. (2014) Assessing the Internal Character, Reservoir Potential, and Seal Competence of Mass-transport Deposits Using Seismic Texture: A Geophysical and Petrophysical Approach. Bulletin AAPG Bulletin 98.4: 793-824.

Bardet, J.-P., C. E. Synolakis, H. L. Davies, F. Imamura, and E. A. Okal. (2003) "Landslide Tsunamis: Recent Findings and Research Directions." Landslide Tsunamis: Recent Findings and Research Directions: 1793-809.

ASTM International, 2003. Standard test method for particle-size analysis of soils (Standard D422-63[2002]). In Annual Book of ASTM Standards (Vol. 04.08): Soil and Rock (I): West Conshohocken, PA (Am. Soc. Testing and Mater.), 10–17

Germaine, J. T. and A. V. Germaine (2009). Geotechnical Laboratory Measurements for Engineers. Hoboken, NJ, John Wiley & Sons, Inc.

Henry, P., T. Kanamatsu, K. T. Moe, and M. Strasser. (2012) "IODP Expedition 333: Return to Nankai Trough Subduction Inputs Sites and Coring of Mass Transport Deposits." Scientific Drilling Sci. Dril. 14: 4-17.

Masson, D. G., C. B. Harbitz, R. B. Wynn, G. Pedersen, and F. Lovholt. (2006) "Submarine Landslides: Processes, Triggers and Hazard Prediction." Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 364.1845: 2009-039.

Mcneill, Lisa, Demian Saffer, Tim Byrne, Eiichiro Araki, Sean Toczko, Nobu Eguchi, and Kyoma Takahashi. (2010) "IODP Expedition 319, NanTroSEIZE Stage 2: First IODP Riser Drilling Operations and Observatory Installation Towards Understanding Subduction Zone Seismogenesis." Scientific Drilling 10, September 2010: n. pag.

Moore, Gregory F., and Michael Strasser. (2016) "Large Mass Transport Deposits in Kumano Basin, Nankai Trough, Japan." Submarine Mass Movements and Their Consequences Advances in Natural and Technological Hazards Research: 371-79.

Moore, G. F., K. Kanagawa, M. Strasser, B. Dugan, L. Maeda, and S. Toczko. (2014) "IODP Expedition 338: NanTroSEIZE Stage 3: NanTroSEIZE Plate Boundary Deep Riser 2." Scientific Drilling Sci. Dril. 17: 1-12.

Moore, Z.T., and D.E. Sawyer. (2014) "Data Report: Particle Size Analysis of Nankai Trough Sediments, IODP Expedition 338 Site C0021." Proceedings of the IODP

Sawyer, D. E., et al. (2012). "Mudflow transport behavior and deposit morphology: Role of shear stress to yield strength ratio in subaqueous experiments." Marine Geology 307–310(0): 28-39. doi: 10.1016/j.margeo.2012.01.009

Sawyer, D. E., R. Jacoby, P. B. Flemings, and J. T. Germaine (2008), Data Report: Particle Size Analysis of Sediments in the Ursa Basin, IODP Expedition 308 Sites U1324 and U1322, Northern Gulf of Mexico, in Proc. IODP, 308 doi: 10.2204/iodp.proc.308.205.2008

Shepard, F. P. (1954), Nomenclature based on sand-silt-clay ratios, Journal of Sedimentary Petrology, 24, 151-158.

Strasser, M., B. Dugan, K. Kanagawa, G.F Moore, S. Toczko, L. Maeda, and the Expedition 338 Scientists, (2014). Proceedings IODP, 338: (Integrated Ocean Drilling Program). doi: 10.2204/iodp.proc.338.2014

Strasser, M., G. F. Moore, G. Kimura, A. J. Kopf, M. B. Underwood, J. Guo, and E. J. Screaton (2011), Slumping and mass transport deposition in the Nankai fore arc: Evidence from IODP drilling and 3-D reflection seismic data, Geochemistry, Geophysics, Geosystems, 12(5), doi:10.1029/2010GC003431.

Talling, P. J., J. Peakall, R. S. J. Sparks, C. O. Cofaigh, J. A. Dowdeswell, M. Felix, R. B. Wynn, J. H. Baas, A. J. Hogg, D. G. Masson, J. Taylor, and P. P. E. Weaver. (2002) "Experimental Constraints on Shear Mixing Rates and Processes: Implications for the Dilution of Submarine Debris Flows." Geological Society, London, Special Publications 203.1:89-103.

Acknowledgements

I would like to thank the Shell Undergraduate Research Experience (S.U.R.E) for providing funding for this research project as well as the Basin Research Lab Group (Josh DeVore, Levent Akinci, Trevor Browning, Jess Hillman, Katie Treiber and Chen Yang) for their help and guidance. Lastly, I would like to thank Zac Moore, the International Ocean Discovery Program, and PGS for providing data and samples for this study.